EMISSION CONTROL TECHNOLOGIES FOR COAL-FIRED POWER PLANTS

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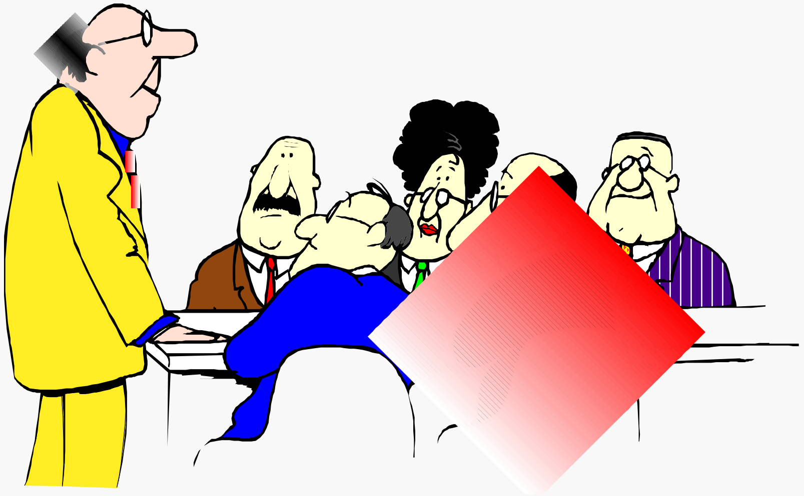
What We'll Cover Today . . .

- **Electric power industry**
- **Pollutant emissions**
- **Control technologies**



Electric Power Industry

- $250 billion in annual electricity sales in 2002; likely to have annual sales between $250 and $270 billion in 2010 to 2015
- Industry operates 16,500 units and 5,700 plants
- There are 3,100 electric utilities, 2,800 IPPs, 230 IOUs, and 2,000 publicly owned utilities
- The industry employs 362,000 people
- In the last five years, we have seen industry spend $88 billion in new power plant investments

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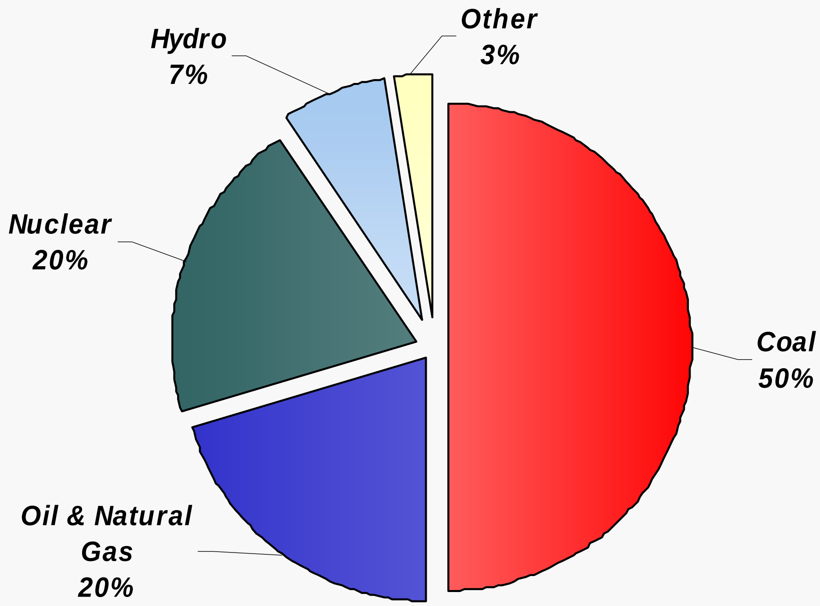
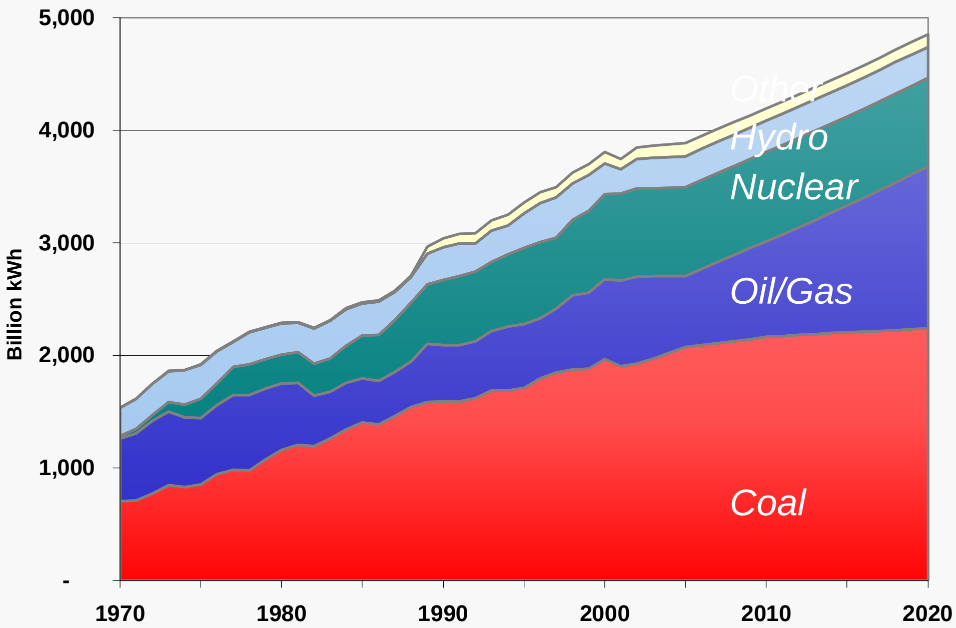
Electricity Generation

Electric Generation in 2002



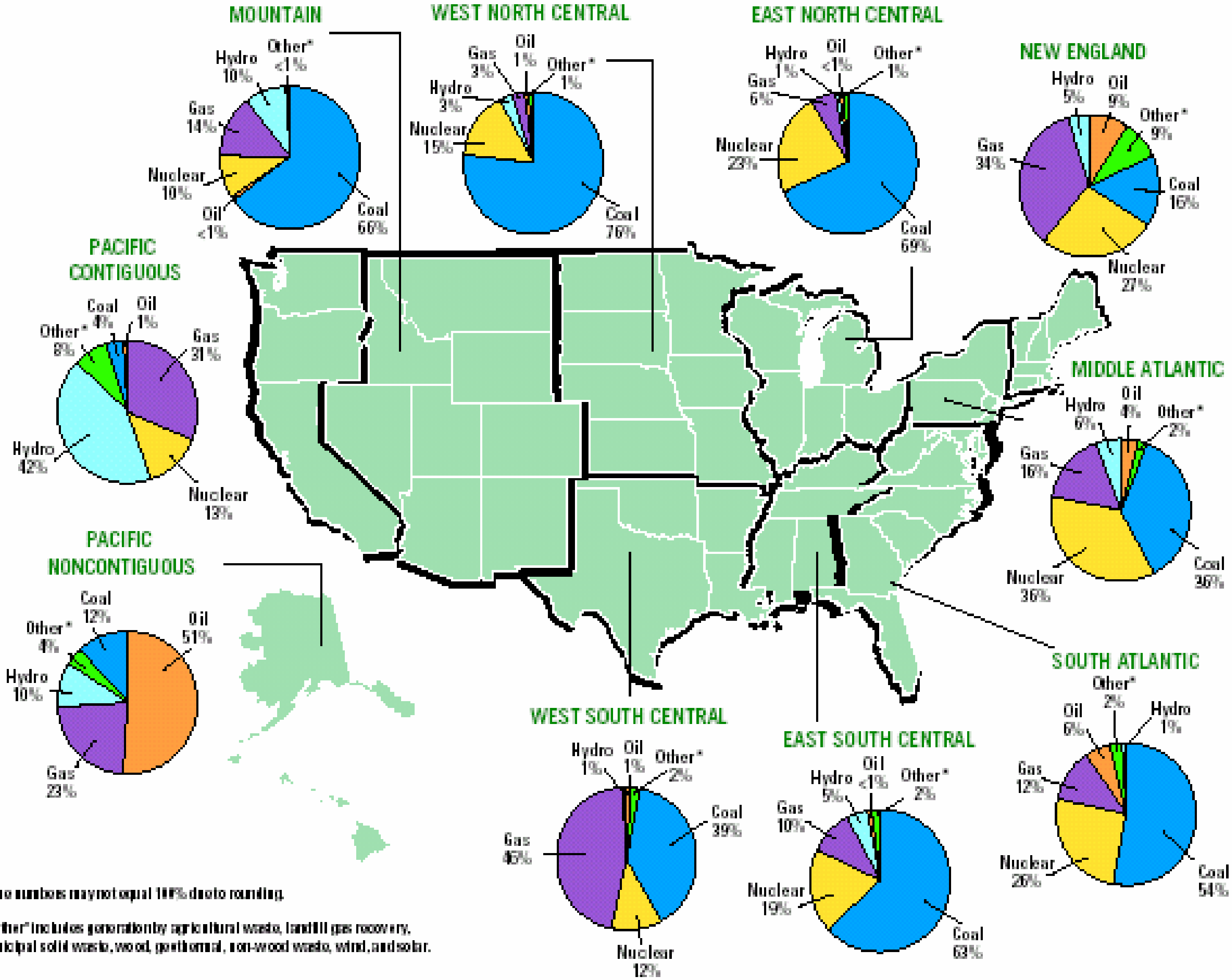
Total Generation = 3,858 billion kWhs

Historical & Projected Electric Generation



Source: 2002 and historical generation is from EIA's Annual Energy Review. Projected generation is from EPA's Integrated Planning Model.

Different Regions of the Country Rely on Different Fuel Mixes to Generate Electricity.



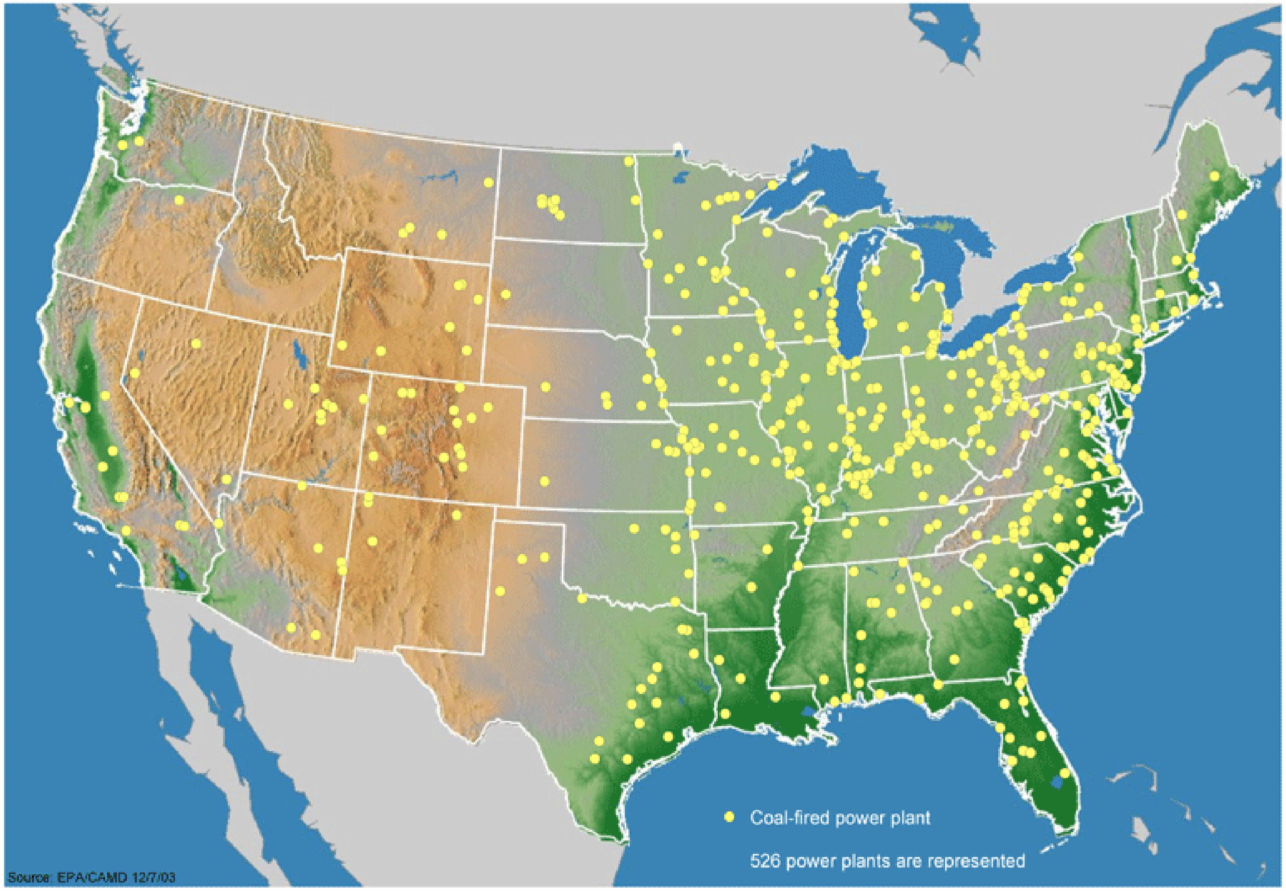
Across the U.S., a diverse mix of fuel is used to generate electricity. Several factors influence an electric company's decision to use particular fuels. These include the price and the availability of supply. This map, arranged by census region, illustrates the diversity of fuel use across the U.S. and shows how the electricity generation mixes in various regions of the country differ. The map further demonstrates that major changes in the generation mix could have economic and reliability impacts, especially on a regional basis.

Source: Energy Information Administration, Annual Electric Generator Report, Utility and Non-Utility Data (2002 Preliminary). By U.S. Census Division.

Some numbers may not equal 100% due to rounding.

* "Other" includes generation by agricultural waste, landfill gas recovery, municipal solid waste, wood, geothermal, non-wood waste, wind, and solar.

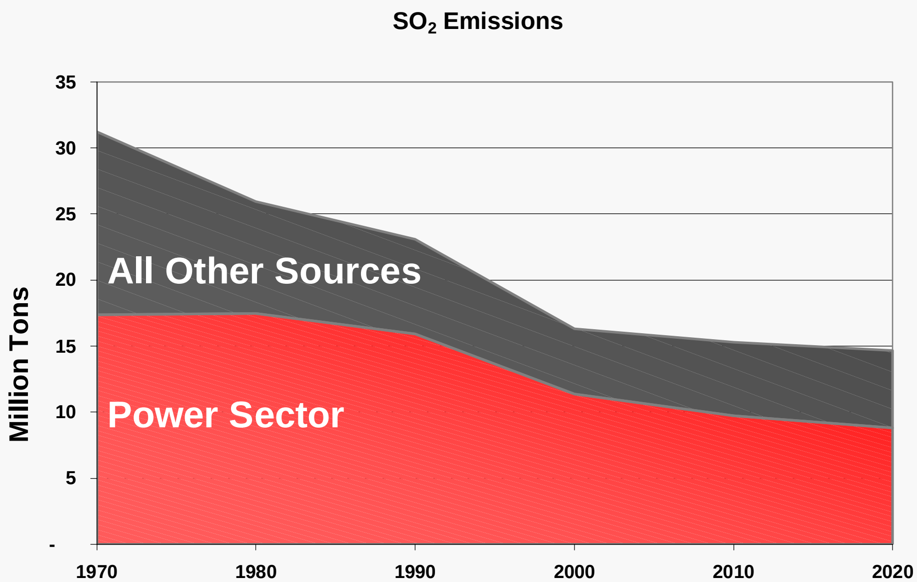
Coal-Fired Power Plants

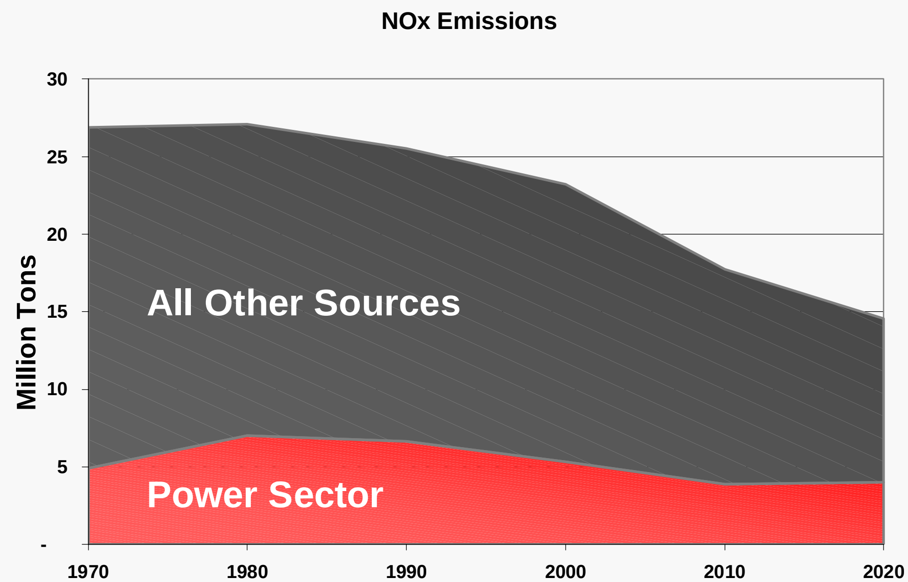


U.S. Coal-Fired Power Plants

- There are about 530 power plants with 305 GW of capacity that consist of about 1,300 units.
- Coal plants generate the vast majority of power sector emissions:
  - 100% Hg
  - 95% SO_2
  - 90% of NOx

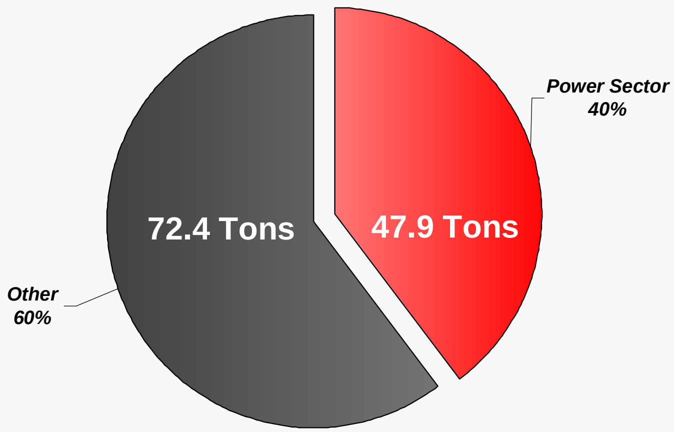
Emissions of SO_2 & NO_x





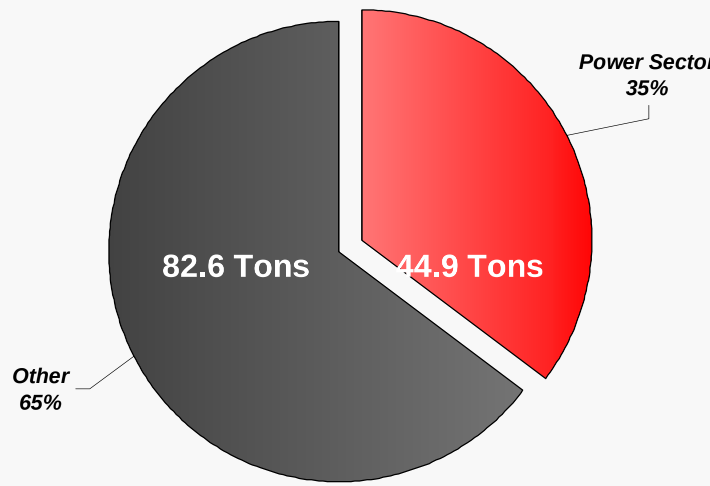
Emissions of Mercury

1999 Mercury Emissions



2020 Mercury Emissions

w/o further controls



Source: EPA

Pollutant Reduction

- Emissions reductions possible through:
  - Emissions control technologies
  - Advanced power generation technologies
  - Power plant upgrading options
  - Fuel switching

- Focus on emissions control technologies

NOx Control Technologies

- Primary – reduce the NOx produced in the primary combustion zone.
  - Widely used - low NOx burners (LNBs) and overfire air (OFA)
- Secondary - reduce the NOx already present in the flue gas
  - Widely used - reburning, selective non-catalytic reduction (SNCR), and selective catalytic reduction (SCR)

Low NOx Burners

- Limit NOx formation by delaying complete mixing of fuel and air
  - Reduced oxygen in primary flame zone
  - Reduced flame temperature
  - Reduced residence time at peak temperature
- Can provide reductions in excess of 50%

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Overfire Air

- 5 to 20% of the total combustion air is injected through ports located downstream of the top burner level
  - Burners operate at lower than normal air-to-fuel ratio resulting in NOx control, OFA added to achieve complete combustion
  - Can be used with LNB to increase NOx reduction by 10 to 25%

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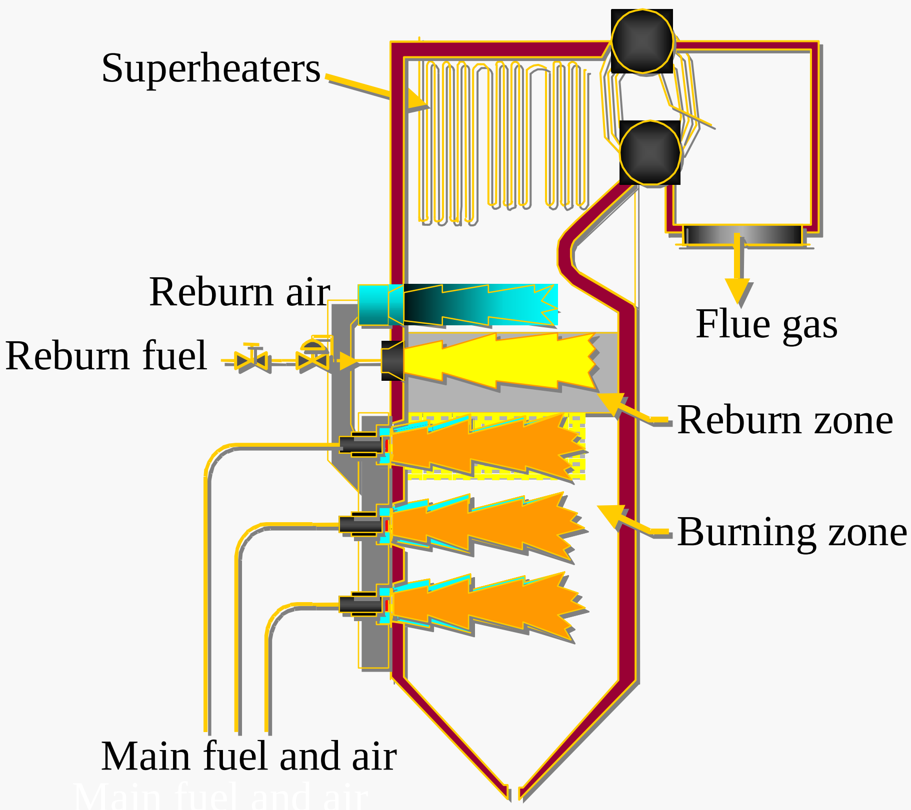
Reburning



- Reburn fuel (natural gas, coal, other fuels) is injected to provide 15-25% of total heat input
- $\geq$50% NOx reduction, mercury and SO_2 reduction
- Low capital costs
- Fuels costs, availability of adequate residence time
- Applications: cyclone, wall, tangential; 33-600 MWe

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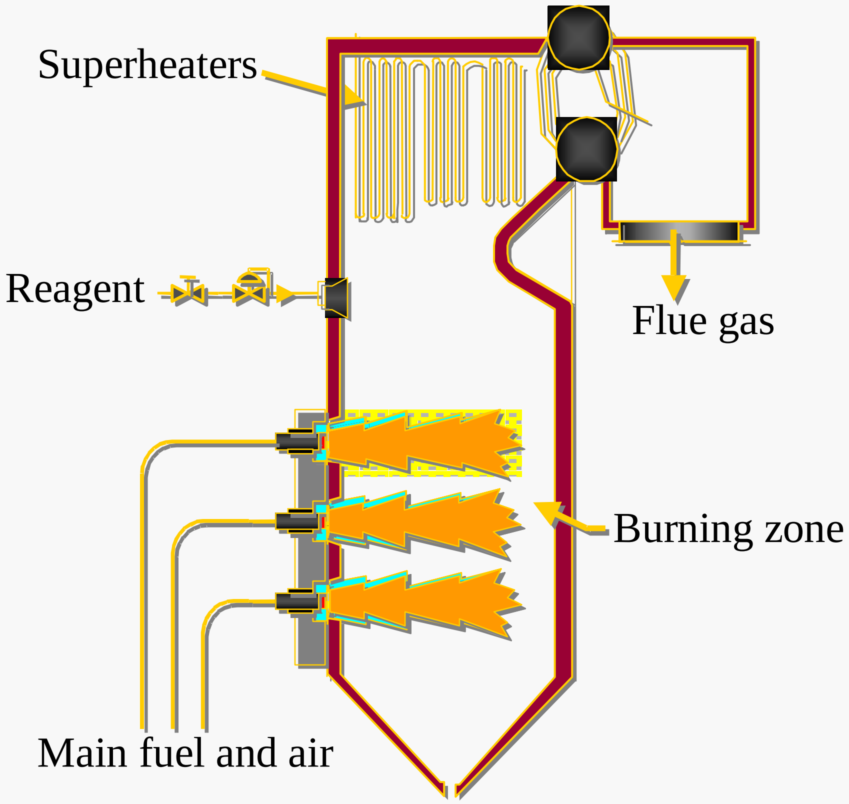
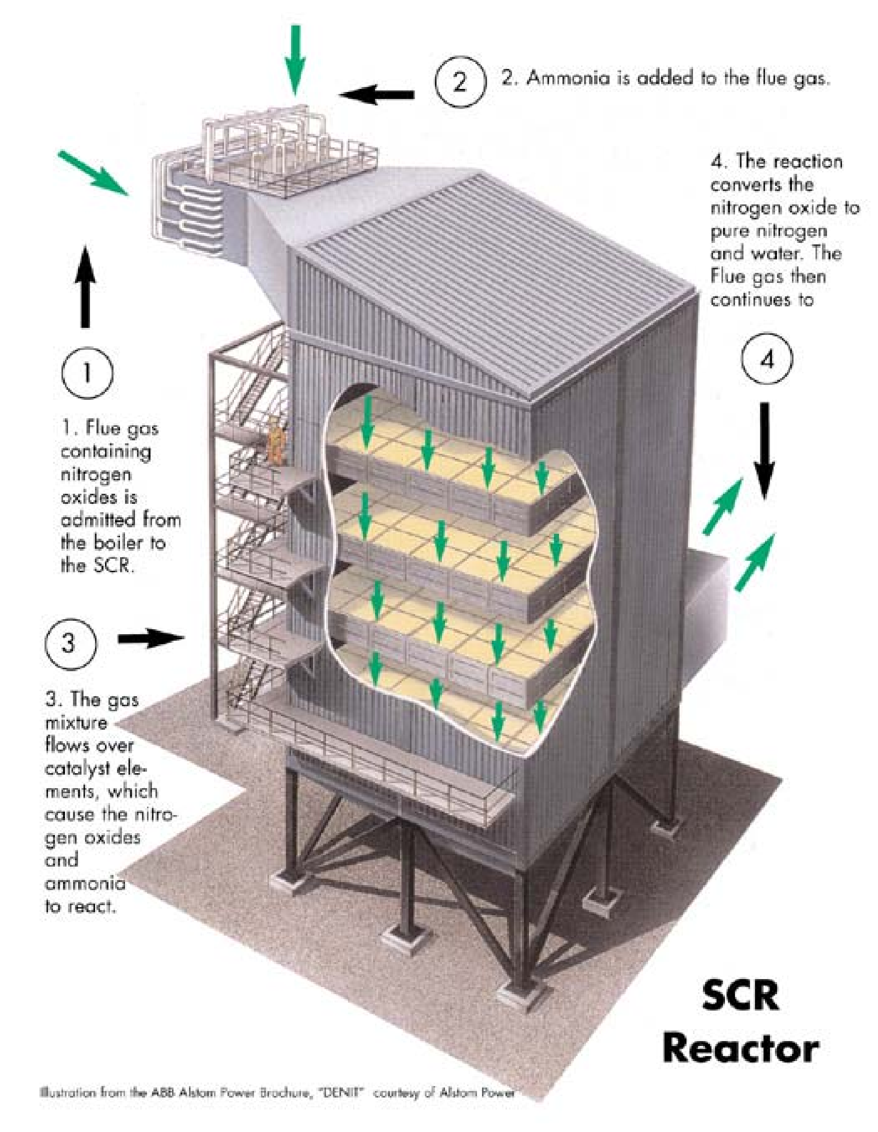
SNCR



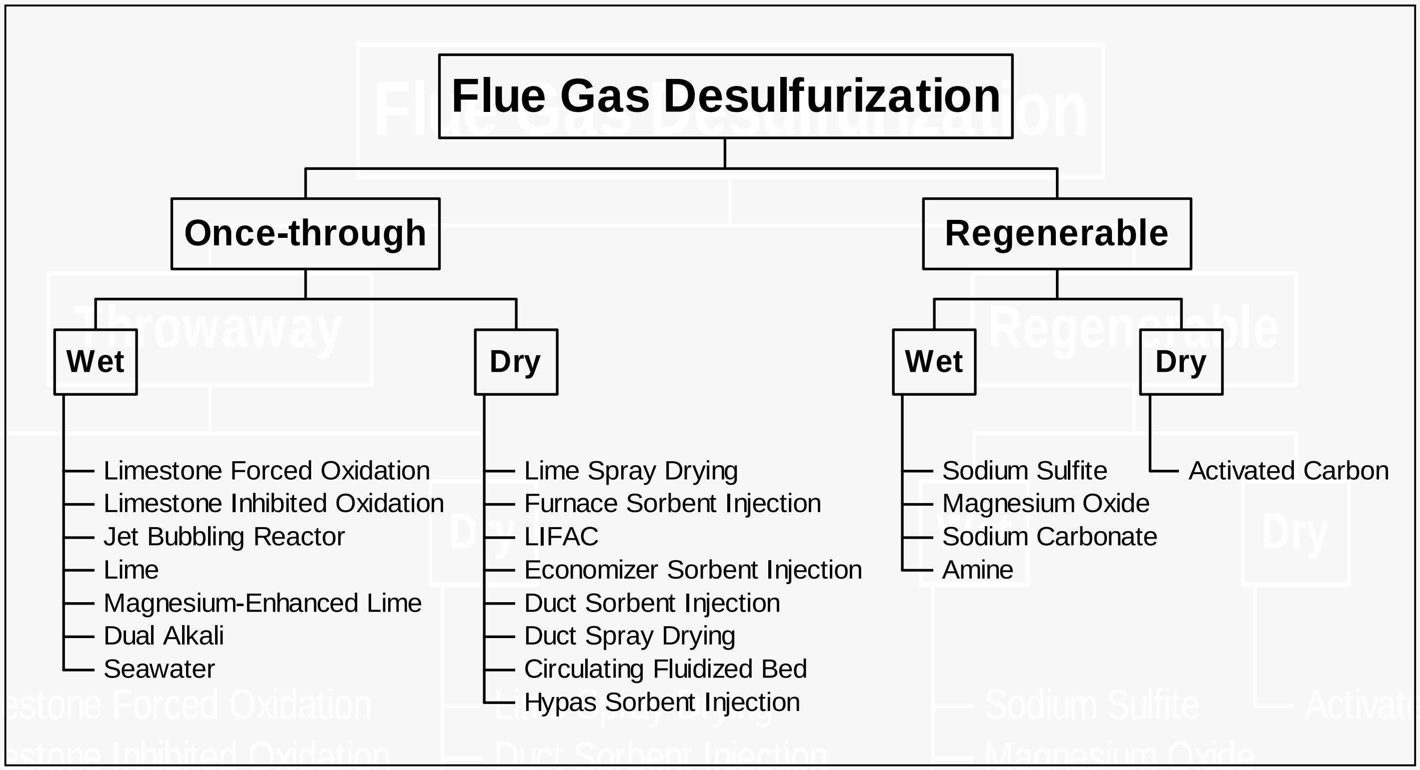
- Urea or NH3 injection, generally between 980 to 1150 ^{o}C
- 30 to 60 % NOx reduction
- Low capital costs
- Load following, NH3 slip, performance on larger boilers
- Applications: cyclone, wall, tangential; 50-620 MW

SCR

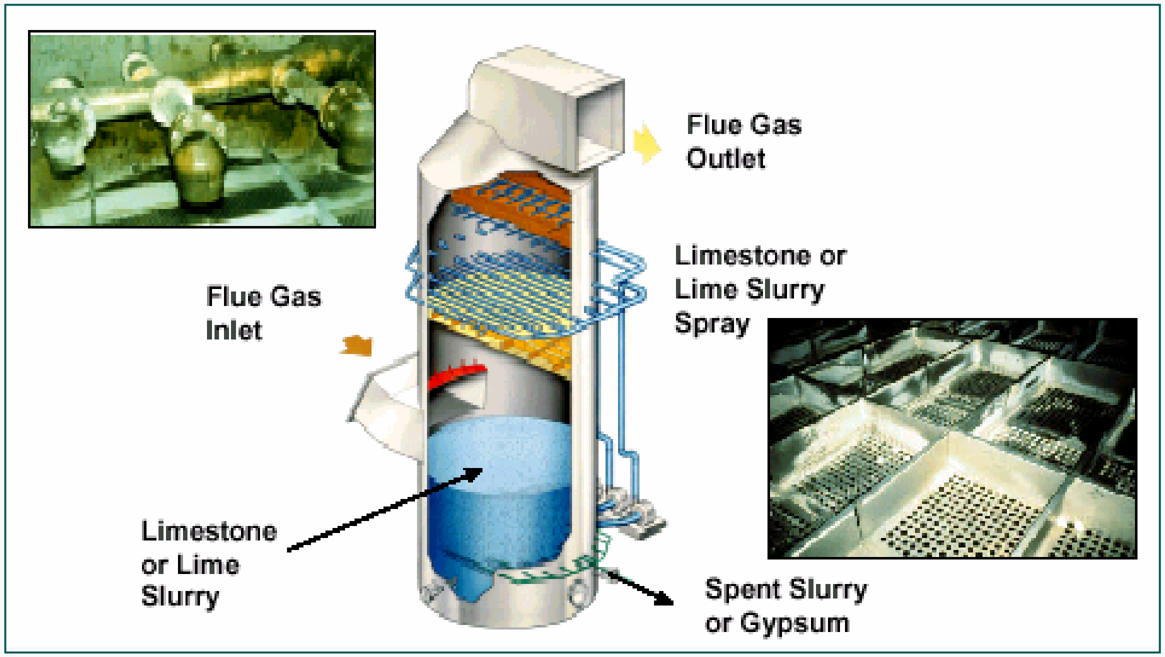


- NH3 injection, generally between 350-400 ^{o}C
- More than 90 % reduction is possible, especially with LNB
- Capital intensive, space requirements, NH_3 slip, SO_3 emissions, catalyst deactivation
- Applications:
  - More than 75 boilers; cyclone, wall, tangential; 122 - 1300 MW

SO_2 Control Technologies



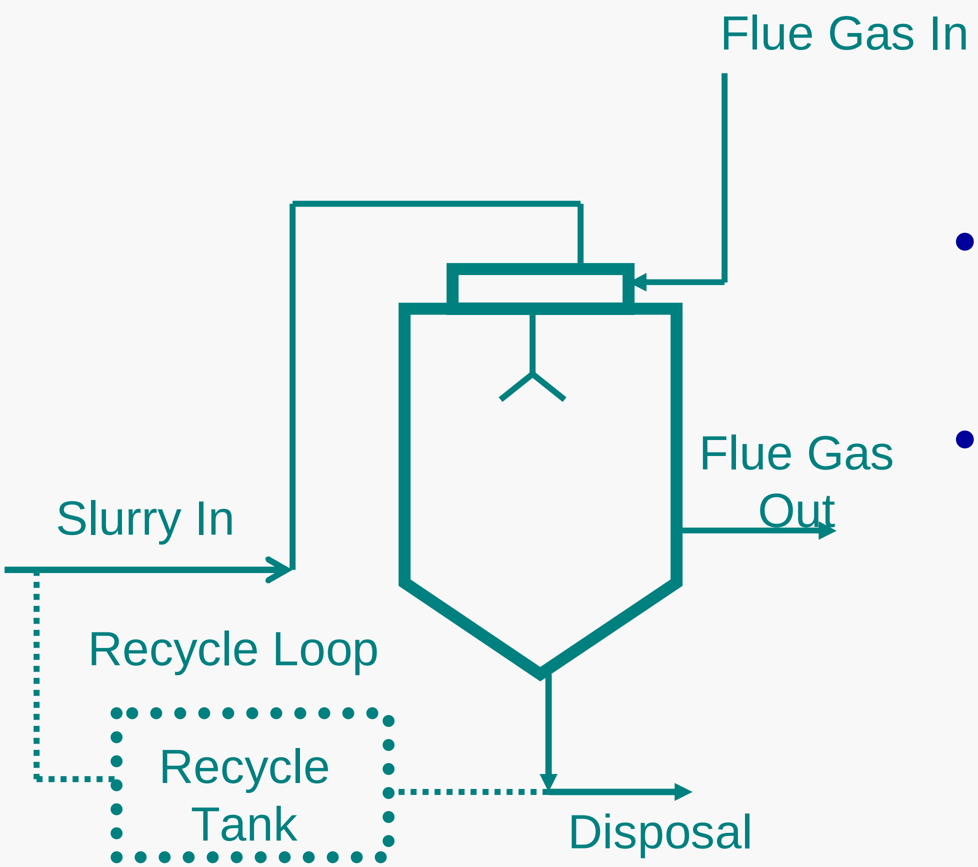
Wet Scrubbers



FGD at Centralia Power Plant

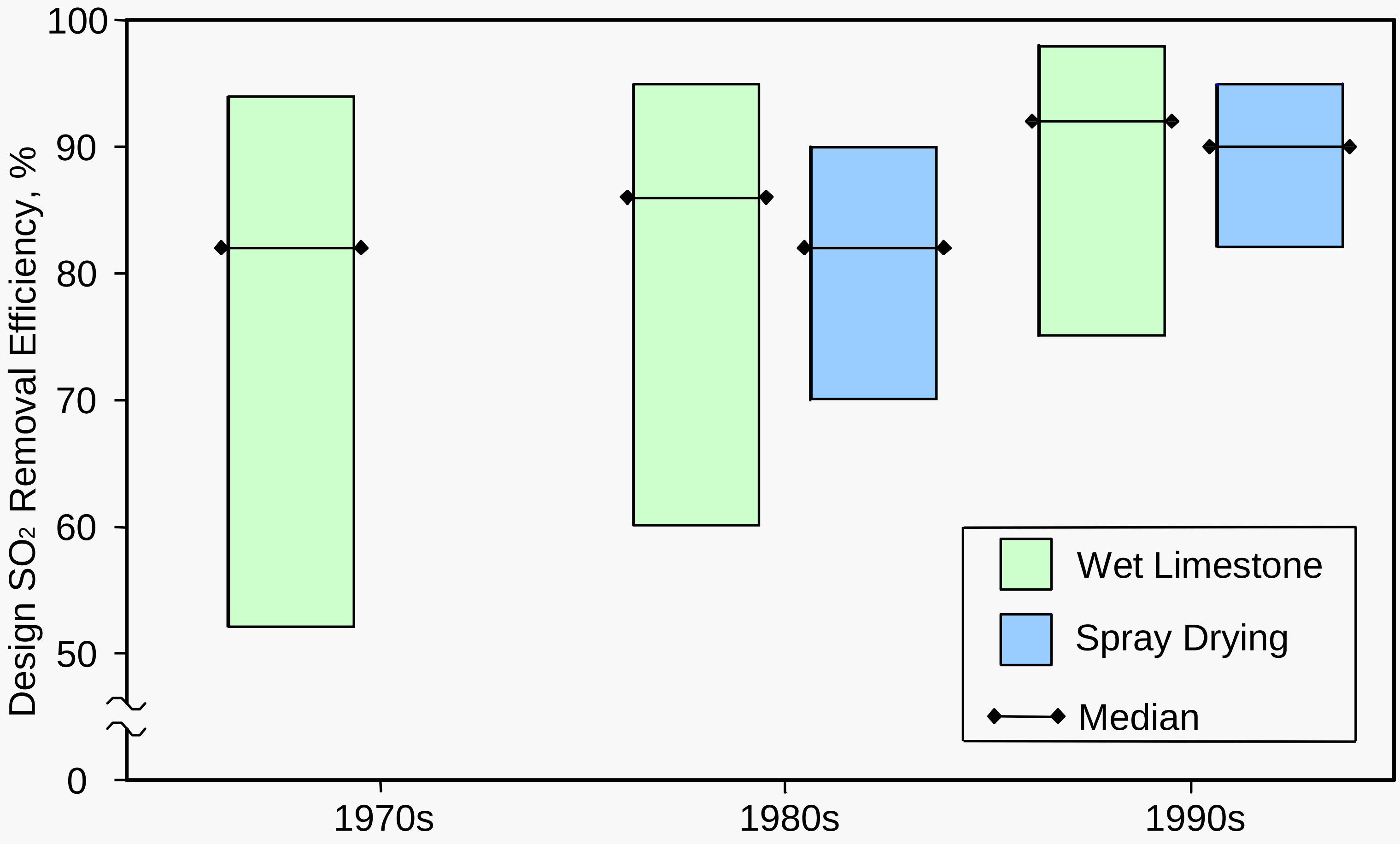
- State-of-the-art is 95% SO_2 removal
- 98 GW (33%) of coal-fired units have scrubbers
- We project 115 GW to have scrubbers by 2010 for Title IV and State regs

Lime Spray Drying

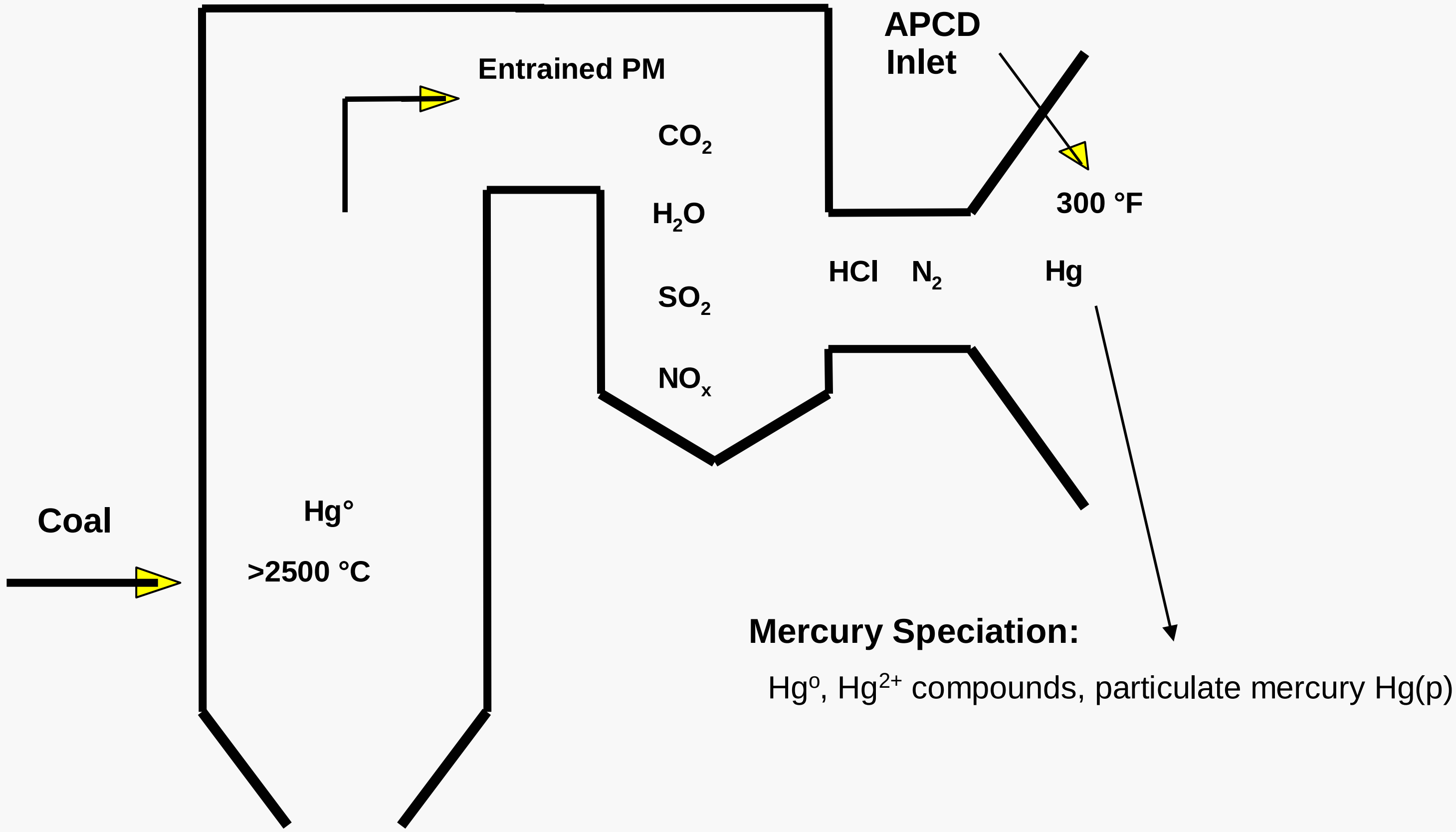


- State of the art is 90% removal
- More than 14 GW of installation

Performance



Mercury in Coal-fired Boilers



Mercury Speciation

- In general, speciation depends on:
  - Coal properties (mercury, chlorine, and ash contents)
  - Time/temperature profile
  - Flue gas composition and fly ash characteristics (carbon, calcium, iron, porosity)
  - Flue gas cleaning conditions

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Mercury Capture in Existing Equipment

<u>Removal in PM Controls</u>

- Mercury can be adsorbed onto fly ash surfaces; Hg^{2+} is more readily adsorbed than Hg^0
- Mercury can be physically adsorbed at relatively lower temperatures (hot-side ESP vs. cold-side ESP)

<u>Capture in Wet Scrubbers</u>

- Hg^{2+} capture depends on solubility of each compound; Hg^0 is insoluble and cannot be captured
- Capture enhanced by SCR

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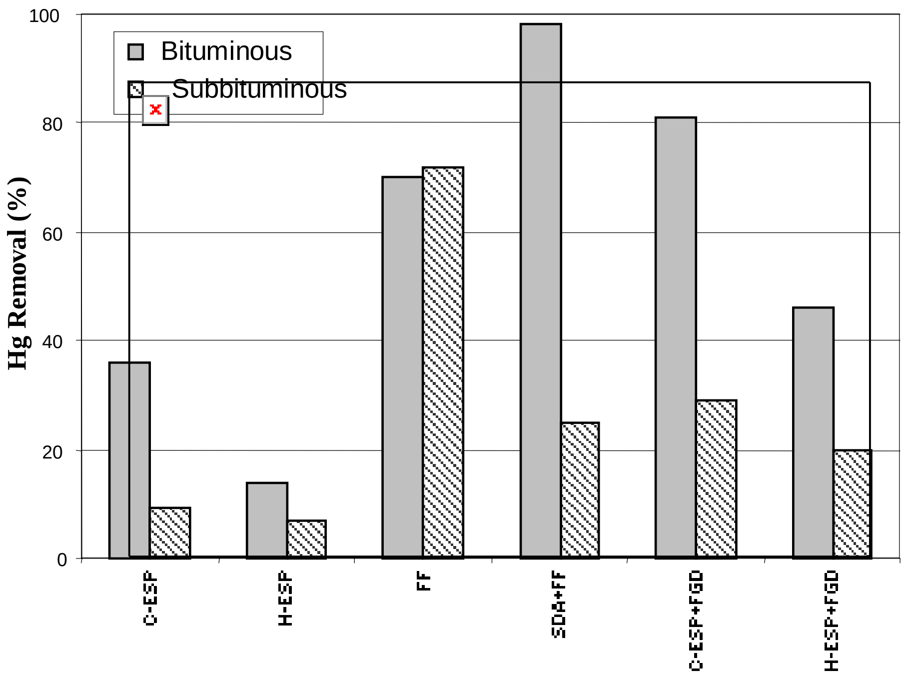
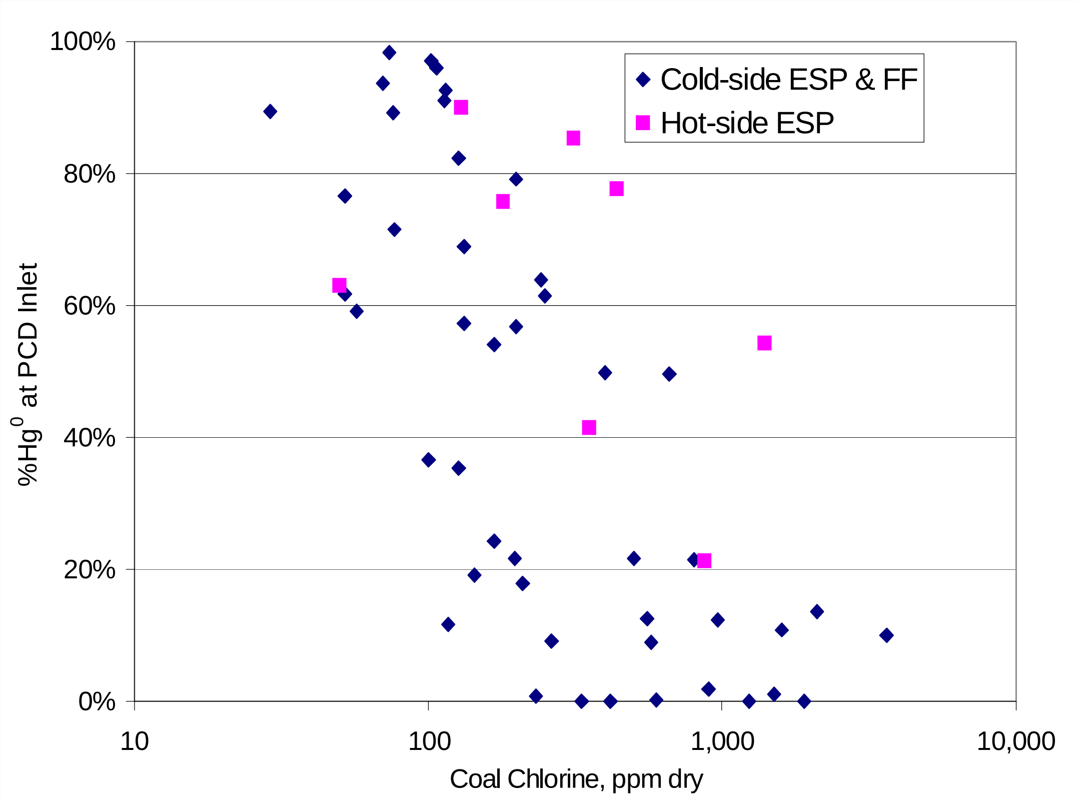
ICR Data



- **Bituminous vs subbituminous**
- **Hg capture for different coal-control technology combinations correlate with coal chlorine content**

Chlorine vs. Mercury Speciation



- ICR data for Hg^0 at ESP & FF inlet
- Hg^0 oxidation appears to be independent of chlorine above 100 µg/g
- Other important factors
  - **Temperature**
  - **Fly ash carbon**

SCR and Mercury Interactions

- Speciation influences emissions control
  - Ionic Hg^{2+} is removed easily by wet scrubbers
  - Volatile elemental Hg^0 is difficult to capture
- SCR units are being used extensively to meet current NOx regulations
- SCR can convert elemental mercury in coal combustion flue gas into the ionic form
  - field data in Europe and U.S. reflects increase in Hg^{2+} across SCR reactor

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SCR-Mercury R&D

- Tested 4 utility plants in the 2001 and 2 in 2002; retested 2 plants in 2002; total of 8 data points
- Oxidized mercury increase across SCR: bit. - up to 71%; subbit. - 10% (one data point only)
- Removal in PM control and FGD (5 data points) - ~ 85% - 90%
- Results from repeated tests were consistent with previous data; impacts of SCR catalyst aging not apparent
- SCR systems with relatively lower catalyst volumes (space velocity greater than 3500 hr-1) also showed significant oxidation increases
- Data gaps: PRB, blends
- Ongoing EPA bench- and pilot-scale research: HCl provides critical chlorine source for Hg^0 oxidation; NOx has a significant promotional effect; SO_x has little effect under the conditions of this study

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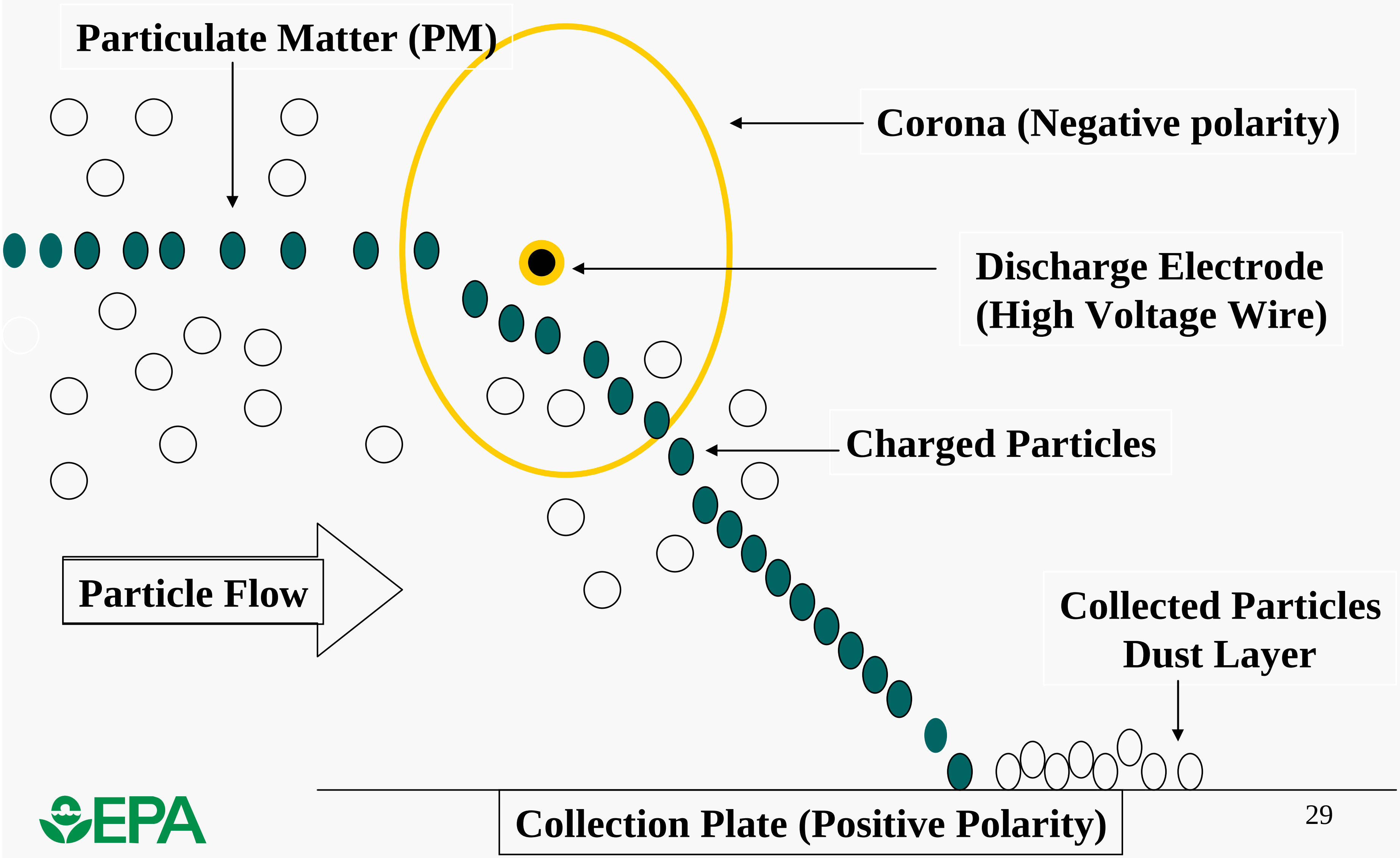
PM Control Technologies for Power Plants

- Electrostatic precipitators (ESPs)
  - 72% of U.S. coal-fired boilers, total PM up to 99.9%, fine PM 80-95%
- Baghouses
  - 14% of U.S. coal-fired boilers, total PM up to 99.9%, fine PM 99-99.8%

Sometimes a picture is worth a …

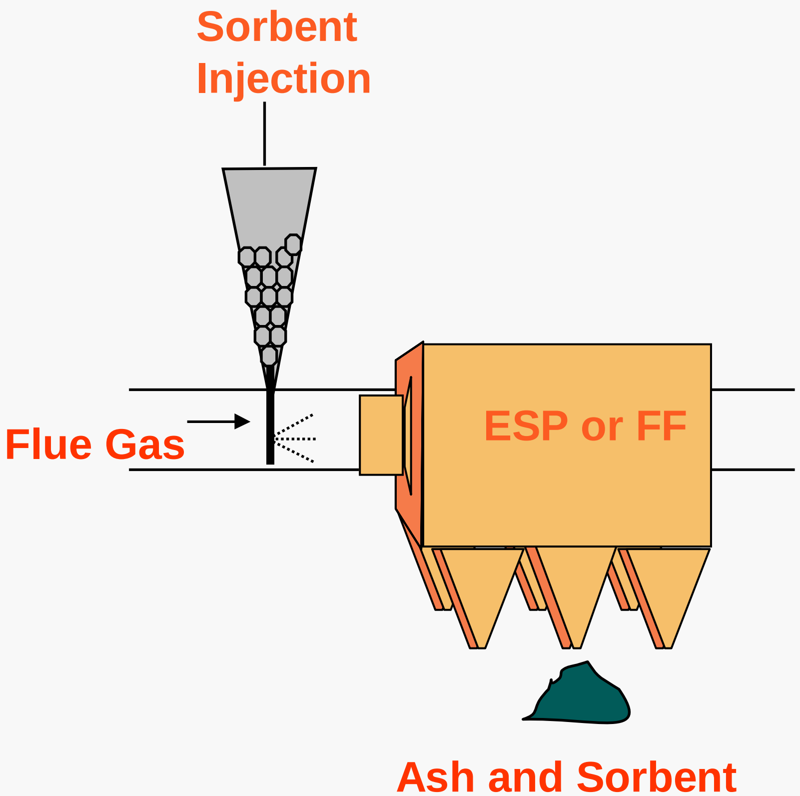
How Does an ESP Work?



Emerging Technologies

Sorbent Injection

- The extent of capture depends on:
  - Sorbent characteristics (particle size distribution, porosity, capacity at different gas temperatures)
  - Residence time in the flue gas
  - Type of PM control (FF vs. ESP)
  - Concentrations of SO_3 and other contaminants



Activated Carbon Injection (ACI)

- ACI successfully used to reduce mercury emissions from waste-to-energy facilities. Effort underway to transfer to coal-fired power plants.
- Not currently installed at any power plant, but short-term testing suggests it may eventually be able to achieve 90% control for all coal types.

Activated carbon injection system

Activated carbon storage and feed system

Carbon Injection Projects

- **Alabama Power E.C. Gaston: unit 3, 270-MW, low-sulfur eastern bit. coals (0.14 ppm Hg and 160 ppm Cl); hot-side ESP, COHPAC baghouse; testing on one-half of the gas stream, nominally 135 MW; wet ash to pond**
- **WEPCO Pleasant Prairie: unit 2, 600-MW, PRB coal (0.11 ppm Hg and 8 ppm Cl); ESP (468 ft^2/kacfm), spray cooling, SO_3 conditioning; testing on one ESP chamber (1/4 of the unit); fly ash sold for use in concrete**
- **PG&E Brayton Point: unit 1, 245-MW, low-S bit. coal (0.03 ppm Hg and 2000-4000 ppm Cl); SO_3 conditioning system; 2 ESPs in series (550 ft^2/kacfm); PAC injection between the ESPs**
- **PG&E Salem Harbor: 85-MW, low-S bit. coal (0.03-0.08 ppm Hg and 206 ppm Cl); ESP (474 ft^2/kacfm); SNCR**

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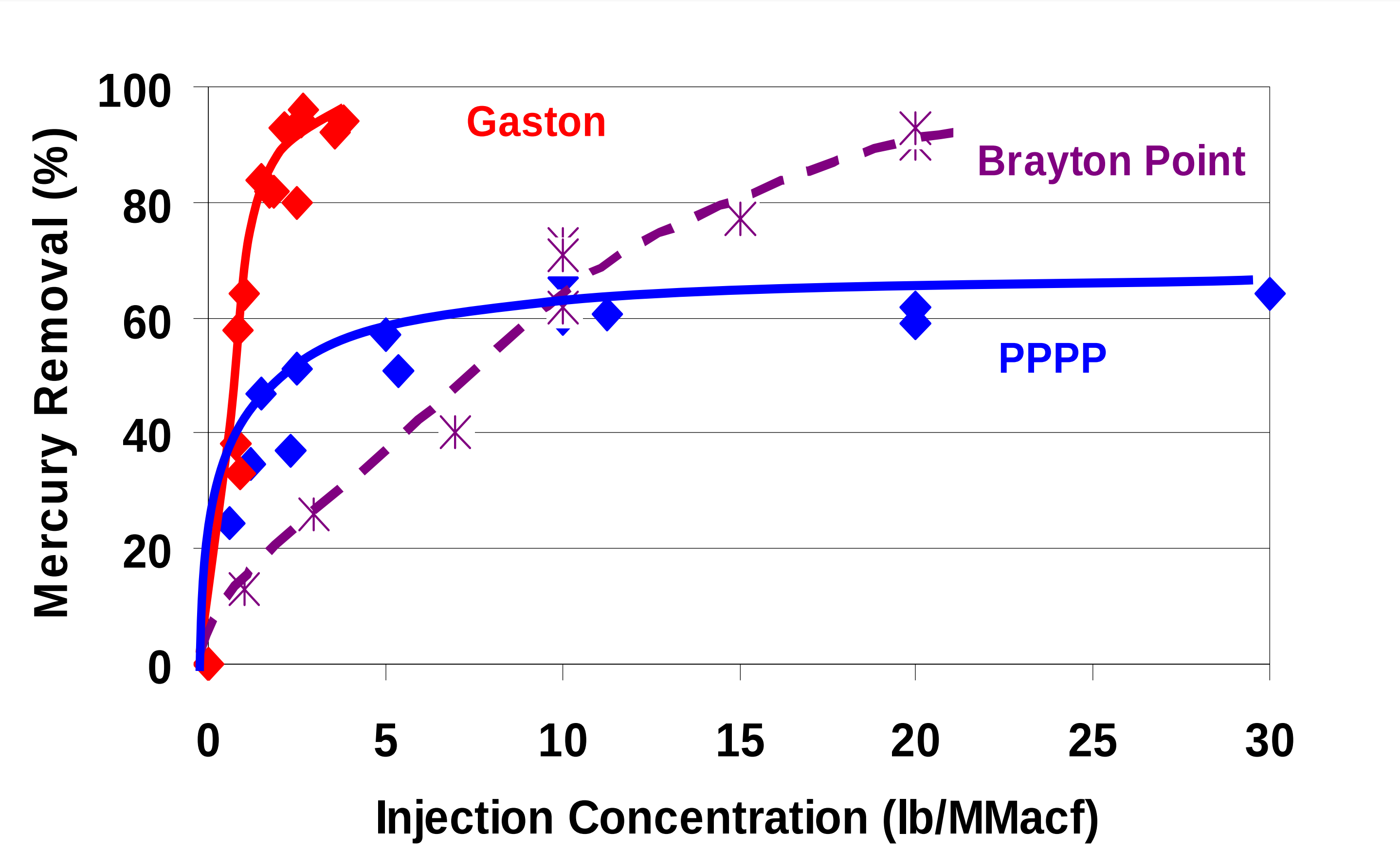
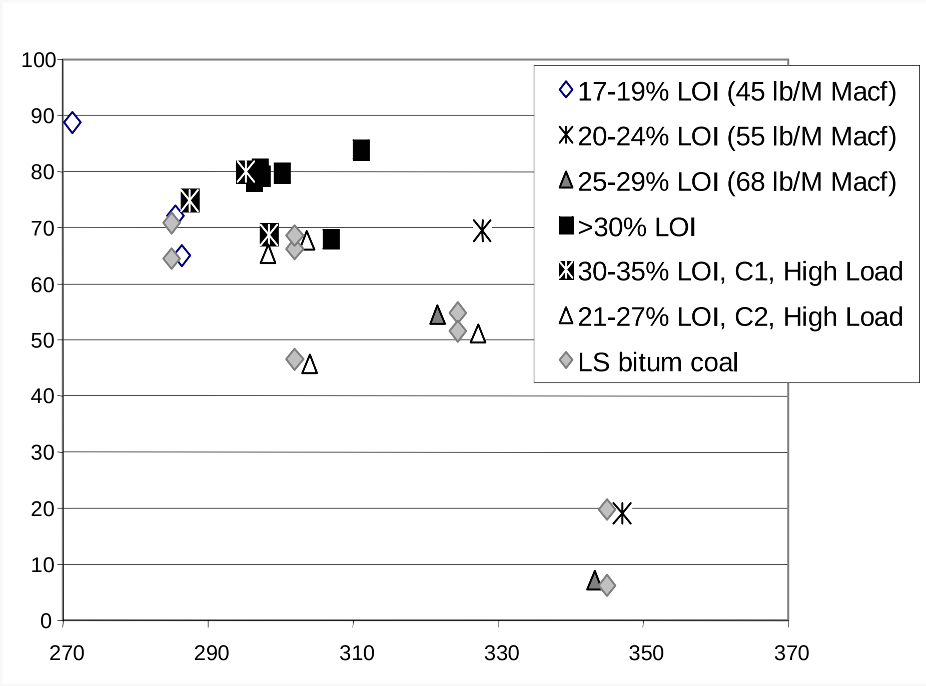
Mercury Removal Trends with ACI



Source: ADA Environmental Solutions (2003)

PG&E Salem Harbor
(w/o PAC Injection)

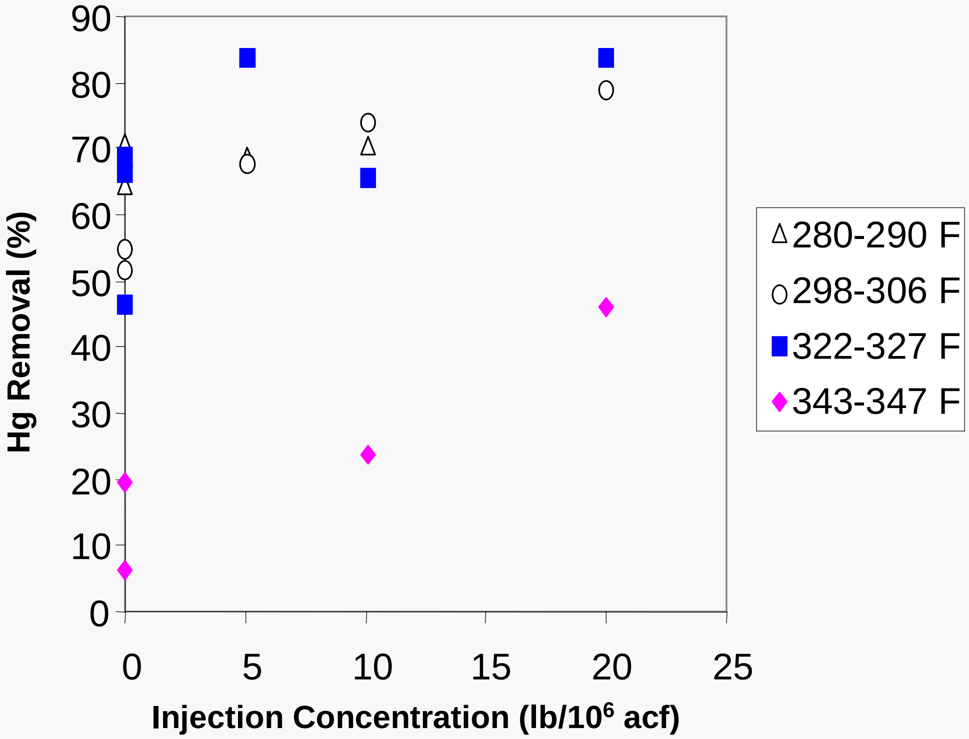
- **85-MW, low-S bit. coal (0.03-0.08 ppm Hg and 206 ppm Cl); ESP (474 ft^2/kacfm); SNCR**
- **High baseline removal due to high levels of LOI; minimal impact on reducing LOI from 30-35% to 15-20% at 300 ºF**
- **Temperature has greater effect than LOI**
- **SNCR has no impact on Hg removal**



Source: ADA-ES

PG&E Salem Harbor
(w/ PAC Injection)

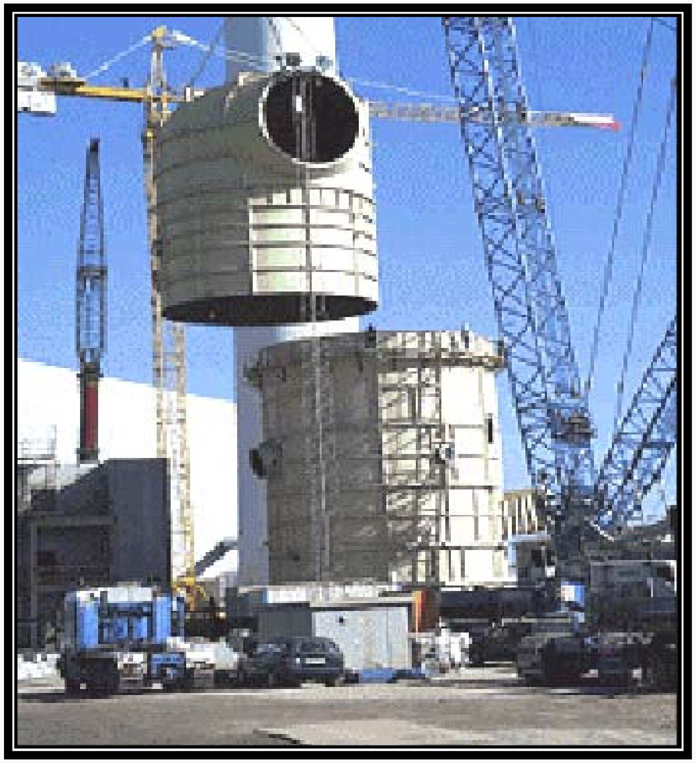
- **At lower temperatures, removal by PAC affected by high baseline removal**
- **At higher temperatures, linear behavior (similar to that at Brayton Point**



Source: ADA-ES

A few more things . . .

Wet FGD Modification



- Capable of removing SO_2 in excess of 95 %
- Can remove oxidized Hg
- Three routes for NO removal:
  - gas phase oxidation to N_2O_5
  - oxidation to NO_2 and reduction to N_2 in the scrubber via sulfate and bisulfate ions
- Investigate SO2, Hg, NOx removal and SO2 to SO3 conversion

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ESFF

- Electrostatically Stimulated Fabric Filtration (ESFF)--developed by EPA
- Pulsejet fabric filter with high voltage electrodes centered between groups of four bags
- Pilot-scale performance data:
  - PM2.5 with ESFF=0.14 mg/m3
  - PM2.5 without ESFF=0.51 mg/m3
  - PM1 with ESFF=0.05 mg/m3
  - PM1 without ESFF=0.17 mg/m3
- BHA Group, Inc. licensee has developed preliminary commercial design

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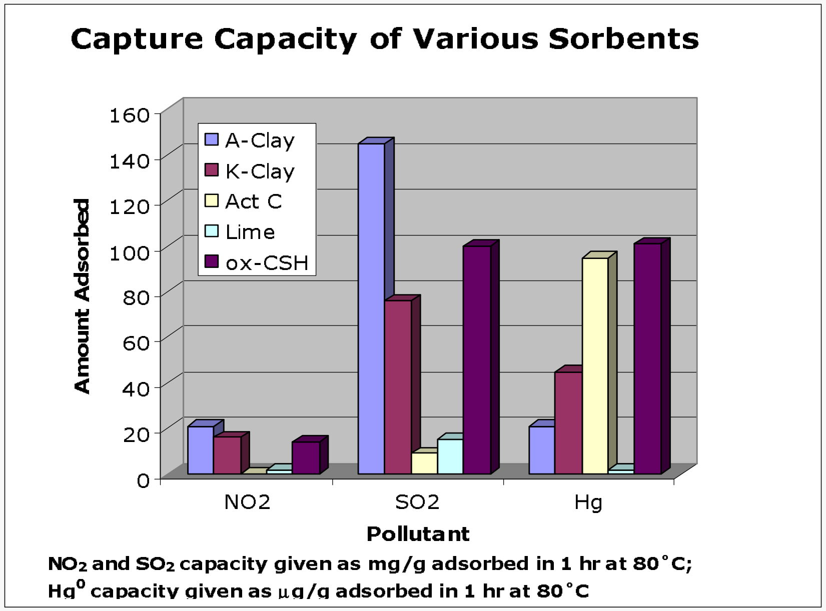
Development of Multipollutant Sorbents



- **Sorbent Development**
  - **Synthesis, Characterization, Evaluation & Optimization**
  - **Relate structure and chemical nature to adsorption characteristics**

•Types of Sorbents Being Studied

- **–Sorbents synthesized using industrial by-products**
- **–Modified carbon-type sorbents**
- **–Surface modified Calcium Silicate Hydrate (C-S-H)**
- **–Multipollutant sorbents that also have adsorptive capacity for CO_2**